AD-A177 486 EXTREME VALUES OF QUEUES POINT PROCESSES AND STOCHASTIC NETWORKS(U) GEORGIA INST OF TECH ATLANTA SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING R F SERFOZO 1/1

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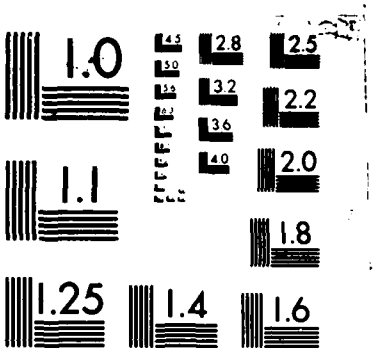

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION NA	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY NA	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE NA	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Georgia Institute of Technology 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION AFOSR/NM
6c. ADDRESS (City, State and ZIP Code) School of Industrial and Systems Engineering Atlanta, GA 30332	7b. ADDRESS (City, State and ZIP Code) Bldg 410 Bolling AFB, DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR 84-0367
8c. ADDRESS (City, State and ZIP Code) Bldg 410 Bolling AFB, DC 20332-6448	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: 6.1102F PROJECT NO.: 2304 TASK NO.: A5 WORK UNIT NO.:
11. TITLE (Include Security Classification) Final report on Extreme Values of Queues Point Processes and ~~Networks~~ Stochastic Network	
12. PERSONAL AUTHOR(S)	
13a. TYPE OF REPORT Annual 13b. TIME COVERED FROM 10/1/84 TO 9/30/86	14. DATE OF REPORT (Yr., Mo., Day) November 30, 1986 15. PAGE COUNT
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL ~~Richard F. Serfozo~~ Ingi Waarts ff	22b. TELEPHONE NUMBER (Include Area Code) ~~404 - 894-2305~~ 767-3025 22c. OFFICE SYMBOL NM

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

FINAL REPORT

Project Title: Extreme Values of Queues, Point Processes and Stochastic Networks

Grant No.: AFOSR 84-0367

Project Director: Professor Richard F. Serfozo
Industrial and Systems Engineering
Georgia Institute of Technology

November 1986

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Extreme Values of Queues, Point Processes
and Stochastic Networks

This two-year research grant consisted of several themes. The following is a summary of our results.

1. Compound Poisson Approximations

Our work on this topic just appeared in Serfozo, R.F. (1986). Compound Poisson Approximations for Sums of Random Variables Ann. Probability, October issue.

During the last 20 years, several theorems have been proved on the convergence of sums of independent random variables to compound Poisson variables. Little was known about how close the sums are to being compound Poisson. Examples were published that seemed to indicate that one could not develop compound Poisson approximations that would be as natural as normal or Poisson approximations.

However, we have been able to develop such approximations. We have proved that a sum of dependent random elements is approximately compound Poisson when the variables are rarely nonzero and, given they are nonzero, their conditional distributions are nearly identical. We have given several upper bounds on the total-variation distance between the distribution of such a sum and a compound Poisson distribution. These bounds are analogous to Berry-Esseen bounds for normal approximations. Our results apply to general random elements such as unions of random sets and sums of random measures or point processes. Our results appear to be useful for characterizing high-level exceedances of dependent variables. We hope to pursue this in the near future.

2. Partitions of Point Processes

Our work on this appeared in Serfozo, R.F. (1985). Partitions of Point Processes: Multivariate Poisson Approximations. Stoch. Process Appl. 20, 281-294.

We proved that when a point process is partitioned into certain sparse subprocesses, then the subprocesses are asymptotically multivariate Poisson or compound Poisson. Using results described above, we derived bounds for the total-variation distance between the subprocesses and their limits. We did this for several types of partitioning rules including independent, Markovian and batch assignment of points. Partitions of point processes are omnipresent in flows of parts in manufacturing networks and distribution systems, and flows of data packets in computer networks.

3. Extreme Values of Birth and Death Processes and Queues

Our work on this has been documented in:

Serfozo, R.F. (1987). Extreme Values of Birth and Death Processes and Queues. Stoch. Processes Appl. (to appear).

Serfozo, R.F. (1986). Extreme Values of Queue Lengths in M/G/1 and GI/M/1 Systems. Technical Report.

In these papers, we solve the long-standing problem of characterizing the asymptotic behavior of the maximum values of birth and death processes and queues over large time intervals. When these processes are positive recurrent, the distributions of their maxima do not converge to a non-degenerate distribution, in the usual way under linear normalizations. We show, however, that by varying the process parameters in a certain way as the time interval grows, then these maxima

do indeed have three possible limit distributions. Two of them are classical extreme value distributions and the other one is a new distribution.

Our results on birth and death processes include conditional limit theorems for maxima of transient processes conditioned that they are finite. For the M/G/1 and GI/M/1 queues, the analysis was more complicated since a certain basic distribution was known only indirectly in terms of ratios of integrals of complex valued functions.

4. Stationary and Reversible Processes

Our work on this appeared in Serfozo, R.F. (1986). Heredity of Stationary and Reversible Processes. Adv. Appl. Probability.

The notion of reversibility plays an important role in characterizing the equilibrium behavior of a network of queues. There are a number of processes associated with a queueing network that are important by themselves. Examples are the number of customers in a certain sector of the network and the point processes of customer flows between pairs of nodes. One frequently confronts the problem: Are these related processes stationary, reversible or ergodic when the network process has these properties? In other words, if a process is stationary, reversible or ergodic, then what functionals of the process have these properties. We answer this by identifying a large class of such functionals. In doing so, we generalize a fundamental result for the heredity of stationarity and we provide an efficient characterization of reversibility that can be used for general random elements such as point processes and random sets.

5. Extremal Problems in Stochast Networks

Our work on this will soon appear in Weiss, G. (1987). Stochastic Bounds on Distributions of Optimal Value Functions With Applications to PERT, Network Flows and Reliability. Operations Research, to appear.

It is generally impossible to obtain tractable expressions for the probability distributions of (1) Critical path lengths in a PERT network, (2) Maximal flows in a network, or (3) Lifetimes of complicated systems. Consequently, it is natural to seek partial information on worse-case bounds of these variables. This can be formulated as a mathematical programming problem. We present an algorithm for solving this problem. The solution can then be used to obtain bounds for general networks.

END

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